



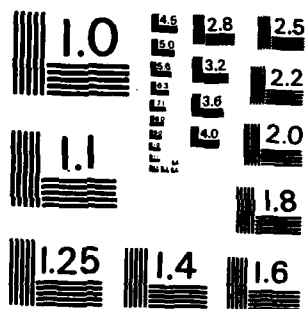
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (1) Generalized Production Rules, Expert Systems, Numerical Estimation of Hidden Variable Values, Distributed Intelligence; (2) Automatic Generation of Descriptive and Normative Theories, Asymptotic Form of a Sequence of Decision Trees, Credit Assignment to Strategy Components, Self-Optimizing Statistical Design Generator, Quasi-Optimum Strategies; (3) Advice Taker/Inquirer System, Acquisition of Strategies via Principles and High-Level Examples, Experientiali- zation, Trainee Evaluation Automated; (4) Interactive Environment for Planning and Decision Making; (5) Integrated System of Strategy Analysis and (CONTINUED)		


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ITEM #20, CONTINUED: Synthesis for Air Traffic Control.

The efforts of the Group for Computer Studies of Strategies centered on five long-term projects: (a) The Generalized Production Rules System (GPRS) is a program which can support decision-making for a variety of expert systems in need of estimates of hidden variables. Hidden variables are such that their values can be identified only at certain times, either intermittently or periodically. In contrast, open variables are readily measureable at any time. The estimation is based on stochastic, causal relations between hidden and open variables. (b) The Quasi-Optimizer System (QO) is a program which observes and measures adversaries' behavior in confrontations, infers their strategies, and constructs a descriptive theory, i.e., a model, of each. It then identifies the components of the strategies, evaluates their effectiveness and combines the most satisfactory ones into a normative theory which is an optimum strategy in the statistical sense. (c) The Advice Taker/Inquirer (AT/I) is a program which can be taught strategies by a human Advisor. The Advisor provides principles and high-level examples of actions in different situations. The system applies the strategy to test, verify and optimize the strategy. (d) The Interactive Environment for Planning and Decision Making uses two graphics screens, one displaying features of the current world, the other those of an extrapolated world with the estimated consequences of tentative decisions. (e) The Integrated System of Strategy Analysis and Synthesis for Air Traffic Control will be useful in teaching and evaluating Air Traffic Control Trainees.



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**AFOSR-TR- 83 - 1346**

APPROACHES TO AUTOMATIC STRATEGY ANALYSIS  
AND SYNTHESIS, PHASE II

Final Scientific Report on Grant AFOSR-82-0340

1 September 1982 - 31 August 1983

Nicholas V. Findler  
Computer Science Department  
Arizona State University  
Tempe AZ 85287

1 September 1983

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**(1) The Generalized Production Rules System (GPRS)**

We have integrated the six modules of the GPRS which were completed during Phase I of our research activity. We have streamlined the whole system, particularly the module that provides the functional estimate of hidden variables (as opposed to point estimates obtained earlier).

We have developed a high-level formalism that enables the user to preview the morphs fitted on a regular terminal and, if satisfied, to plot them on a multi-colored plotter.

We have also started working on a complex optimization program. Its objective is to arrive at an optimum set of values for five parameters which are currently specified by the user (in a somewhat arbitrary manner). These are: (i) the initial length of the "window" that defines the minimum number of datapoints to determine a trend; (ii)-(v) the lower bounds of two statistical measures (F-ratio and R-square) used in deciding whether datapoints should be added and dropped, respectively, at the two ends of the window.

We also intend to use GPRS for econometric explication.

**(2) The Quasi-Optimizer System (QO)**

We have streamlined the existing modules, particularly QO-1, QO-2 and QO-3. The module QO-5 has now extended facilities in generating a redundancy-free Super Strategy. The module QO-6 has two algorithms implemented, one using local features and the

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MATTHEW J. KERPER  
Chief, Technical Information Division

other one global features, in computing (i) identity, (ii) a measure of similarity, and (iii) equivalence between two decision subtrees.

We are in the process of also extending Q0-1, Q0-3 and Q0-4. The modules Q0-1 and Q0-3 will have an inductive discovery capability to identify any correlation between different components of a strategy response vector. Furthermore, Q0-1 will be able to act also in the passive observation mode. This will yield, as a by-product, the probability distribution of the decision making environments. Using this result, we can compute the "expected value of a strategy" as well as reduce both the depth and breadth of the decision trees used.

The scope of Q0-1 and Q0-3 is also being extended to include symbolic variables (ordered and unordered categories, rank numbers, etc.)

We are in the process of enabling Q0-4 to provide the necessary information for a "meta-strategy" that shifts the domain of confrontation to a region in which a given strategy is most proficient.

### (3) The Advice Taker/Inquirer (AT/I) System

Significant progress has been made with regard to AT/I. We have completed modules that

- .accept principles and high-level examples given by the advisor;

- .generalize examples into as broad principles as other

principles permit;

- .convert the stored principles into a strategy;

- .check a strategy so constructed for consistency and completeness.

However, more than 80% of the work on this system remains to be done yet.

#### (4) The Interactive Environment for Planning and Decision Making

We have started designing a system which uses two graphics screens connected to a computer. One would display the relevant features of the current real world. (It is updated either with a user-defined frequency, or when an event from a user-specified list occurs or when the user demands it momentarily.) The other graphics display would show the relevant features of the real world extrapolated to a user-specified time point in the future. This would indicate the consequences of the user's tentative decisions, as computed by a model of the world in the computer. If satisfied, the user finalizes his decision. Otherwise, he modifies them as long as its consequences are not at least as good as desired.

A learning process, also planned, would improve the model of the world so that when real time "catches up" with "extrapolated time", the display of the current world is identical or sufficiently similar to the stored image of the extrapolated world.



(5) The Integrated System for Strategy Analysis and Synthesis for Air Traffic Control (ATC)

We have started system design work on how the three systems described first should be integrated in the last described man-machine environment. Such a system would be used to model ATC trainees automatically, generate a normative ATC strategy, provide a feedback to the trainees concerning the quality of their strategies, and to perform other tasks.

We have also started using a voice recognition system for ATC commands in a simulated air space.

**PUBLISHED WORK:**

During Phase II of our research activity the following publications were completed:

(1) Findler, N. V.: A multi-level learning technique using production systems (Cybernetics and Systems, 13, pp. 25-30, 1982).

(2) Findler, N. V.: Implications of Artificial Intelligence for Information Retrieval (Proc. ACM82 Conf., p. 187; Dallas, TX, 1982).

(3) Findler, N. V. and E. Morgado: Morph-fitting -- An effective technique of approximation (Accepted by the Journal of Mathematics and Computers in Simulation).

(4) Findler, N. V.: An expert subsystem based on generalized production rules (Proc. Sixteenth Hawaii Internat. Conf. on System Sciences, 1983, pp. 401-405, Vol. 1).

(5) Findler, N. V., N. Mazur and B. McCall: A note on computing the asymptotic form of a limited sequence of decision trees (Information Sciences, 28, pp. 207-231, 1983).

(6) Findler, N. V., J. E. Brown, R. Lo and H. Y. You: A module to estimate numerical values of hidden variables for expert systems (Internat. Journal for Man-Machine Systems, 18, pp. 323-335, 1983).

(7) Findler, N. V.: A preliminary report on a self-optimizing experimental design-generator (Proc. COMSTAT82, Fifth Internat. Symposium on Computational Statistics, Toulouse, France. Proceedings to be published by Physica Verlag: Würzburg, West Germany, 1983).

(8) Findler, N. V. and R. Lo: A note on the functional estimation of values of hidden variables -- An extended module for expert systems (Internat. Journal for Man-Machine Systems, 18, pp. 555-565, 1983).

(9) Findler, N. V. and A. Ralston: Theory or Practice? Concerns of Computer Science education in a developing country (Invited paper for the First Internat. Information Conf. in Egypt; Cairo, Egypt, 1982).

(10) Findler, N. V.: On a computer-based theory of strategies (Kybernetes, 12, pp. 89-97, 1983).

(11) Findler, N. V.: An overview of the Quasi-Optimizer system (Accepted by Large-Scale Systems -- Theory and Applications).

(12) Findler, N. V.: Automatic analysis and synthesis of strategies: A new branch of Artificial Intelligence (Proc. IEEE Phoenix Conf. on Computers and Communication, pp. 239-245, 1983).

(13) Findler, N. V. and R. F. Crompt: An Artificial Intelligence technique to generate self-optimizing experimental designs (Submitted for publication).

(14) Findler, N. V. and B. B. McCall: A conceptual framework and a heuristic program for the credit assignment problem (Submitted for publication).

(15) Findler, N. V.: On automatic generation of descriptive and normative theories (Invited paper, IEEE Internat. Conf. on Systems, Man and Cybernetics, Bombay and New Delhi, India, 1983).

(16) Findler, N. V., M. S. Belofsky and T. W. Bickmore: On some issues concerning optimization and decision trees (Proc. Internat. Conf. on Mathematical Modelling, Zurich, Switzerland, 1983).

(17) Findler, N. V.: Some Artificial Intelligence contributions to air traffic control (Submitted for publication).

(18) Findler, N. V., G. L. Sicherman and B. McCall: A multi-strategy gaming environment (In M. Bramer (Ed.): Game-Playing Programs: Theory and Practice, Ellis Horwood: Chichester, England, 1982).

(19) Findler, N. V.: Artificial Intelligence (In A. Ralston and E. D. Reilly, Jr. (Eds.): Encyclopedia of Computer Science, Second Edition; Van Nostrand: New York, 1983).

(20) Findler, N. V.: Heuristic Programming (In A. Ralston and E. D. Reilly, Jr. (Eds.): Encyclopedia of Computer Science, Second Edition; Van Nostrand: New York, 1983).

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